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AUTHOR Gentile, J. Ronald; And Others
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ABSTRACT

Previous research on analogy solutions indicated that an associative relatedness process was central to the solution process. One implication of these findings was that differences in associations to the words comprising the items may produce differences in test performance and, hence, account for the vast differentials in performance of persons of various ethnic and sociocultural groups. This study tested this hypothesis by selecting two groups of college students of markedly different backgrounds and with large differences in analogy test scores. Predictability of analogy item rankings from ranked associative relatedness ratings within each of the samples fell within the range found in previous studies. It was not possible, however, to attribute differential test performances to different associates of the group. (PR)

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Associative Relatedness as a Predictor of
Differential Performances on Analogy Items¹

J. Ronald Gentile
State University of New York at Buffalo

Leon H. Belcher
Texas Southern University

Joel T. Campbell
Educational Testing Service

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ABSTRACT

Previous research on analogy solutions indicated that an associative relatedness process was central to the solution process. One implication of these findings was that differences in associations to the words comprising the items may produce differences in test performance and, hence, account for the vast differentials in performance of persons of various ethnic and sociocultural groups. This study tested this hypothesis by selecting two groups of college students of markedly different backgrounds and with large differences in analogy test scores. Predictability of analogy item rankings from ranked associative relatedness ratings within each of the samples fell within the range found in previous studies. It was not possible, however, to attribute differential test performances to different associates of the group.

One of the most difficult challenges to cognitive, as well as to measurement, theorists has been to account for differences in performance on standardized aptitude and achievement tests among various subgroups of the population (such as urban vs. rural, male vs. female, black vs. white, etc.). A primary reason for this difficulty, of course, is that the processes subjects use in solving test items is not well understood, and until a theory of the cognitive processes elicited by test items is developed, it would be difficult, if not impossible, to account for differences in solutions.

Recognizing the importance of studying the processes involved in test item solutions, a program of research was begun to delineate the components of the analogy solution process and thereby provide a theory of problem solving ^{on} analogy items (Gentile, 1967 and 1968; Gentile, Kessler and Gentile, 1969). Implicit in these studies was the hope that such a delineation in time would provide an accurate prediction of individual differences in the solution of these items. Analogies of the following form were selected as the items to be studied since they are considered to be measures of reasoning, and since they are quite widely used in standardized tests:

FIRE: ASHES::

1. winter:ice
2. tree:leaves
3. Christmas:holly
- + 4. event:memories

Although the previously cited studies do not specify the processes of analogical reasoning in any but a pre-theoretical (i.e., incomplete)

manner, there was a repeated finding that an associative mechanism accounted for the major proportion of the variance in the solution process. Specifically, rankings of the associative relatedness (the Word Relatedness Rating Scale, see Gentile and Seibel, 1969) of the four-word groups which comprise each alternative choice (e.g., FIRE ASHES WINTER ICE, FIRE ASHES TREE LEAVES, etc.) consistently predicted the ranked solutions of the analogy items. Supporting a causal interpretation was an experimental study in which primed associates in a pre-training task were shown to affect subsequent analogy solutions (Gentile et al., 1969)^{Exp. III}. Such data led Gentile et al. to conclude that "the process that Ss use in solving analogy items is primarily an associative process" and that the measure of associative relatedness used...^{Cu} appears to account for from 28% to 50% of the variance in the analogy solutions" (p. 501).

Assuming that such variance estimates are approximately accurate, this finding implied a simple explanation for the differential performances of different subgroups of the population--namely, that differences in associations to the words comprising the items are responsible for the differences in test performance. This suggestion can be inferred from the work of many investigators (e.g., Bernstein, 1960; Hertzler, 1965; Jensen, 1967, John, 1963;) and is certainly not a new hypothesis. On the other hand, the analogy studies cited above almost mandated some test of the hypothesis along the lines of the previous studies. This paper presents a study designed to yield preliminary data on that question.

METHOD

General Overview.^P The general hypothesis under test throughout the several previous studies was that the preferences of alternative choices

of analogy items could be predicted from knowledge of the relatedness of the words comprising those alternative choices. To measure this, subjects are required to rank the analogy alternative choices from best to worst (1 to 4 or 1 to 5 for four- or five-choice items, respectively). The rankings of the alternative choices obtained from this group by summing across individuals within items constitute the criterion to be predicted. These subjects are thus referred to as the criterion group.

Another group of subjects receive the Word Relatedness Rating Scale (WRRS) in which they are asked to rate on a nine-point scale (from Extremely-Easy-to-Relate to Very-Difficult-to-Relate) "how difficult it would be for you to write sentences showing how the words above the rating scale are related or go together." The words to be rated for relatedness are the four word groupings which comprise each alternative choice in an analogy item. In the sample item, for instance, two of the sets of words to be rated would be FIRE ASHES WINTER ICE and FIRE ASHES TREE LEAVES. These ratings on each set of four words are summed across subjects within each analogy item, and these summed ratings are ranked from highest to lowest relatedness (1 to 4 or 1 to 5 for four- and five- choice items, respectively). These group rankings constitute the predicted rankings for each item, and this group of subjects is called the predictor group.

Using this general procedure, support for the hypothesis that different associates are responsible for different analogy solutions would be obtained if each of the following conditions held. First, two groups of subjects must be sampled from populations very different in experiential backgrounds (and presumably therefore in associative responses to words) and whose performances on analogy items are markedly different. Second, within each sample, WRRS ratings should reliably

predict analogy solutions within the range of previous studies. Third, there should be zero order between-sample correlations on the WRRS ratings and on the analogy item solutions.

Subjects.

Subjects were 98 students from Lycoming College (LC), Williamsport, Pa. and 104 students from Texas Southern University (TSU) Houston, Texas. Gross comparisons of the two schools on the only available data indicated that the socio-economic situations were sufficiently different to justify the assumption that the two samples for this study were drawn from different populations. For example, in 1968-69 LC had an enrollment which included 1.2% blacks, the total estimated cost of an academic year (including tuition, room and board, books, and fees) was \$2700-3200, and the mean family income of students on aid programs (about $\frac{1}{2}$ of the student population) was \$8797 per year.² In contrast, TSU had a 1968-69 enrollment which was 98% black, had a total estimated academic year cost of \$1460, and had 65% of the Freshmen coming from families earning less than \$6000 per year.

The LC students serving as subjects were both underclassmen and upperclassmen enrolled in four classes: elementary statistics, educational psychology, developmental psychology, and advanced sociology (reported in Gentile et al; 1969, Exp. IV). The TSU subjects were all Freshmen enrolled in ^aX reading and study skills course.

Analogy Items.

Fifteen analogy items, selected from the semi-secure item files of Educational Testing Service, and previously used by Gentile et al. (1969) in Exp. IV were used in this study. These items cannot be printed here because of their semi-secure classification, but they are similar in form to the sample item in the introduction of this paper, with the

exception that the present items have five alternative choices. One random order of items was used for all subjects.

Procedure.

In each of the regularly scheduled classes referred to above, subjects were assigned to the criterion group (LC: N=50; TSU: N=56) or to the predictor group (LC: N=48; TSU: N=48) by a procedure which insured only that subjects with adjacent seats were in different groups.

As noted above, the criterion group solved the fifteen analogy items concurrently with the predictor group's rating the word sets on the WRRS. In addition to the 75 sets of words to be rated by the predictor group (five in each of the 15 analogy items), six trios of word pairs selected from the Palermo-Jenkins (1964) norms and ten sets of word triplets selected from the Nunnally-Koplin (1967) norms were included for validity data. The Palermo-Jenkins word pairs, which had been used in the studies referred to previously, were selected from the norms so that subjects rated a given stimulus word three times: paired with a high, medium, and low frequency response (e.g., CHAIR TABLE, CHAIR SEAT, and CHAIR KITCHEN, respectively, were one trio of word pairs). In addition, trios of word triplets were randomly selected from the Nunnally-Koplin Joint Meaningfulness table, according to the same rule, to give a stimulus pair combined with a high, medium, and low response word (e.g., CORN FIELD FARM, CORN FIELD CROP, and CORN FIELD ROOTS were one trio of triplets to be rated).

All of these sets of words - 75 four-word sets from the analogy items, 30 three-word sets from the Nunnally-Koplin norms, and 18 two-word sets from the Palermo-Jenkins norms - were placed in the rating booklet in one random order for all subjects. Because of two misspelled words in the booklet used at LC, one analogy item and one Nunnally-

Koplin set had to be discarded from the analysis, leaving 14 analogy items and 9 Nunnally-Koplin sets for the LC analyses only.

RESULTS

As noted earlier, a comparison necessary before the test of the hypothesis of interest is that of whether the two samples differ in analogy solutions. Therefore, the proportion of correct solutions (as Keyed by Educational Testing Service) was obtained for each subject. The mean proportion of correct responses for the LC sample was .56 (S.D.=.16), while for the TSU sample it was .25 (S.D.=.12), yielding a $t_{96} = 12.775$, $p < .001$.

The predictability for each of the 15 analogy items for the within-sample, as well as the between-sample, comparisons were all calculated by the procedure in Table I, which presents the TSU data on predictability of the analogy item solutions (the criterion) from the WRRS ratings (the predictor). Table I shows these data cast into a Friedman Two-Way ANOVA by Ranks table (Siegel, 1956) in which the heading row is the analogy rankings of the TSU criterion group and the body of the table presents the TSU predictor group rankings for each item.

 INSERT TABLE I ABOUT HERE

Q This analysis yielded a $\chi^2_r = 26.28$ ($p < .001$, $df=4$), which indicates a highly significant relationship between the predicted (by the WRRS ratings) and actual (from analogy solutions) rankings for the 15 analogy items for the TSU subjects. The extent of this relationship was estimated by calculating the mean rank-order correlation of these 15 items, which was .65.

Similar procedures were used to estimate the interrelationships between the various combinations of LC and TSU predictor and criterion

groups, and the mean correlations are presented in Table 2. Included in Table 2 as the correlation of variables 3 and 4 is the .65 rho discussed in the last paragraph. The comparable data for the LC group is the correlation of variables 1 and 2, which was .53. These results indicate that the WRRS ratings do predict significantly the analogy solutions within both the LC and TSU groups. Interpretation of the remaining correlations in Table 2 are deferred to the discussion.

INSERT TABLE 2 ABOUT HERE

Similar analyses were conducted on the normative pairs of Palermo-Jenkins and trios of Nunnally-Koplin (presented in Table 3).

INSERT TABLE 3 ABOUT HERE

DISCUSSION

The mean rank-order correlations presented in Table 3 replicate the previous relations between the WRRS and normative measures of associative relatedness (Gentile and Seibel, 1969; Gentile et al., 1969), and add further support to the argument that within both the LC and TSU students sampled, associative relatedness reliably predicts analogy solutions. Thus far, then, the results of this study satisfy the first two conditions necessary (see the General Overview) for the hypothesis of different associates being responsible for different solutions to analogy items. The final condition to be satisfied is to obtain zero-order correlations between-samples on the WRRS ratings of words in analogy items³ and on analogy solutions.

Returning to Table 2, however, presents difficulties for the hypothesis, since the mean correlation⁴ between the LC and TSU students on the WRRS ratings was .72. This indicates good agreement between the samples on the relatedness of word groups. Further, although there was a very large difference in proportion of analogies solved correctly (i.e., ranked 1), there was a significant tendency for both samples to rank the alternative choices of each analogy item in a similar manner, as indicated by the mean rho of .49. These two correlations indicate that there is substantially more agreement between the TSU and LC students in their ratings of associative relatedness of words than was expected (supporting the results of a normative study by Belcher and Campbell, 1968).

The final two correlations to be discussed are extremely interesting and provocative. The LC WRRS ratings correlate .69 with the TSU analogy solutions, which is as high as the WRRS ratings of the TSU predictor

group correlated with the analogy solutions of the TSU criterion group: .65. In contrast, the TSU WRRS ratings show a zero-order correlation ($\rho=.25$) with the LC analogy solutions. This finding suggests that the analogy solution process of the TSU students is much more of an associative process than is the process used by the LC students.

In other words, analogy items appear to be solved by some mechanism whereby the words comprising each alternative choice are compared along the dimension of associative relatedness. However, the solution process of those subjects who score poorly on analogy items includes more of this associative relatedness mechanism than does the process of those subjects who serve well (an interpretation suggested by Willner, 1964). The something extra that the high scorers^y do remains to be specified, concurrently with an elucidation of the remaining dimensions of the processes required to solve analogy items.

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FOOTNOTES

1. Appreciation is extended to Mr. John J. Fremer, Jr. of Educational Testing Service for his aid in obtaining the items used in this study; to Mr. John G. Hancock, Dr. David J. Loomis, Mr. Lee B. Ross, and their students for permission to use their class time to collect these data; to Mr. Hunter M. Breland for transcription of data; and to Miss Delores Kessler Kennedy and Mrs. Patricia K. Gentile for their help during several stages of this study.
2. Presumably the family income of students not receiving aid was higher, although data were not available.
3. There is no necessary contradiction between expecting zero-order correlations between samples on the WRRS ratings of words appearing in analogy items and large positive correlations between samples on the WRRS ratings of words appearing in the norms, because the latter are high frequency words in the language, while the former cover the range from very frequent to very infrequent.

TABLE 1

Predictability of Rankings of Alternative Choices on 15 Analogy Items
for the TSU Students

	Analogy Rankings (Criterion)					Abs. Diff.	rho
	1	2	3	4	5		
1	3	5	2	1	4	10	-.200
2*	1	4	3	2	5	4	.675*
3	2	1	4	3	5	4	.800
4	2	1	4	3	5	4	.800
Items 5	2	3	1	4	5	4	.700
6	1	2	5	3	4	4	.700
7	1.5	1.5	4	3	5	3	.875
8	1	2	3	4	5	0	1.000
9	1	4	2	5	3	6	.500
10	3	1	2	4	5	4	.700
11	1	2	3	4	5	0	1.000
12	1	4	3	2	5	4	.600
13	1	2	3	4	5	0	1.000
14	2	3	1	4	5	4	.700
15	2	3	5	4	1	8	-.100
Sum	24.5	38.5	45	50	67		

Note: Criterion rankings (row 1) are based on 48 Texas Southern University students' analogy solutions. Predictor rankings (body of table) are based on 56 TSU students' WRRS ratings. $\chi^2_r = 26.28$ ($p < .001$, $df = 4$). Mean rho = .65.

*includes a 3.5 tie on the analogy rankings: one is therefore considered a 3, the other a 4, in a conservative direction for calculation of χ^2_r . The tie is included in the calculation of rho.

TABLE 2

Mean Rank-Order Correlations of Analogy Solutions and
Word Relatedness Ratings of Lycoming College Students
and Texas Southern University Students

Variables	2	3	4
1. Analogy Solutions (LC) N = 50	.53	.49	.25*
2. WRRS (LC) N = 48		.69	.72
3. Analogy Solutions (TSU) N = 48			.65
4. WRRS (TSU) N = 56			

Note: χ^2_r values association with each mean rho provided above were
all highly significant ($p < .01$ or better) except * ($p > .10$).

TABLE 3

Mean Rank-Order Correlations of Word Relatedness Ratings and Two Sets of Norms (Palermo-Jenkins and Nunnally-Koplin) for Lycoming College Students and Texas Southern University Students

Variables	2	3	4
1. Palermo-Jenkins Norms	--	.75	.92
2. Nunnally-Koplin Norms		.78	.60
3. WRRS (LC) N = 48			.63
4. WRRS (TSU) N = 56			

Note: χ^2_r values associated with each mean rho provided above significant ($p < .05$ or better).